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Renewable energy in buildings in China—A review

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ABSTRACT

Utilizing renewable energy in buildings helps to reduce consumption of conventional energy and to achieve low carbon economy. The past decades have witnessed a rapid development of renewable energy in buildings globally. China is no exception. The policies, regulations and strategic plans related to renewable energy in buildings are critically analyzed in this study with an aim to present an integrated policy framework. Furthermore, the current situation of utilizing various types of renewable energy resources in buildings and main barriers are discussed. Finally the development plan for renewable energy in buildings is presented according to the national policies. This study offers a comprehensive and systematic reference for the renewable energy in buildings in China.

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1. Introduction

During the last two decades, the rapid growth of Chinese economy has created a massive demand for energy (see Fig. 1). In 2010, the total energy production was 2969 million tonnes of coal equivalent (tce), tripled than that in 1991. The annual increase rate of energy consumption is about 6.2% during the same period, reaching 3249 million tce in 2010. On the other hand, coal dominates the energy consumption structure of China, accounting for as high as 68% of the total energy consumption in 2010 [1]. As a result, China has become a net energy importer [2]. Furthermore, the highly energy intensive economy and strong GDP growth in

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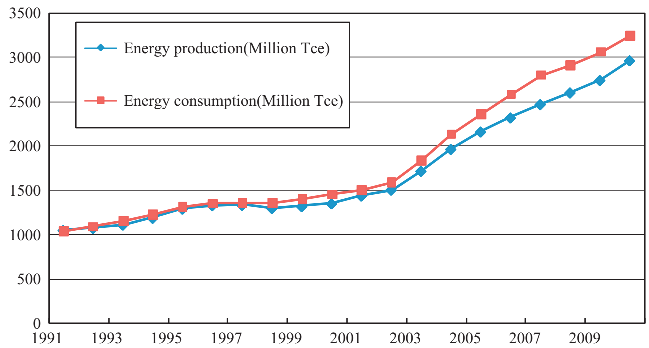


Fig. 1. Energy production and consumption in China.
Source: China Statistical Yearbook [1].

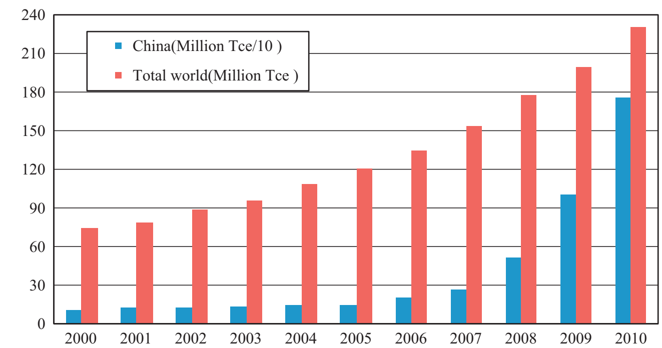


Fig. 2. Renewable energy consumption in China and the world.
Source: BP Statistical Review of World Energy [24].

China will inevitably drive the continuous growth of the energy demand [3].These present key challenges to China to balance between rising energy demands and potential environmental issues [4,5].

Renewable energy helps to mitigate the tension between the energy demands and public concerns on environmental pollution [6,7]. In recent years, the renewable energy capacity expands dramatically around the world and more than 85 countries have adopted renewable policy targets by 2010 [8]. Renewable energy plays a critical role in achieving low carbon economy, especially for China. The abundant reserve of renewable energy sources will help China to reduce the high intensity of carbon dioxide emission per unit of GDP. Recently, the Chinese government has promulgated a number of policies, regulations and strategic plans to promote the development of renewable energies. For instance, China is the world's largest producer and consumer of solar water heater at present [3,9]. Energy consumption from renewable energy resources will account for 15% of total energy consumption by 2020 [10].

With the rapid growth of economy, the building sector has become one of the biggest contributors towards energy consumption and greenhouse gas emission. According to the statistics of the U.S. Energy Information Administration, the buildings sector accounts for some 20% of the total energy consumption around the world [11]. In China, the residential building sector consumed 338.43 million tce, accounting for 11% of the national overall energy consumption and ranked second across all sectors in 2009 [1]. This proportion will even increase further in the future [12]. In the past two decades, the annual increase rate of building energy consumption in China is more than 10% [13]. To achieve low carbon economy, China has devoted to utilize renewable energy in buildings. Various types of energy consumption in buildings, such as cooling, heating, hot water, lighting as well as household appliance energy consumption, can be supplied by renewable energy systems [14–16]. Similarly, the utilization of renewable energy also features in sustainability reporting of leading international construction companies [17]. This study aims to investigate the utilization of renewable energy in buildings in China by reviewing the energy consumption in buildings as well as analyzing the relevant policies, regulations and strategic plans in China.

2. Analysis of renewable energy and energy consumption in buildings

2.1. Utilization of renewable energy

Common renewable energy resources include solar energy, wind energy, geothermal energy, ocean energy, featured with recyclability and low level of environmental pollution [18–21].

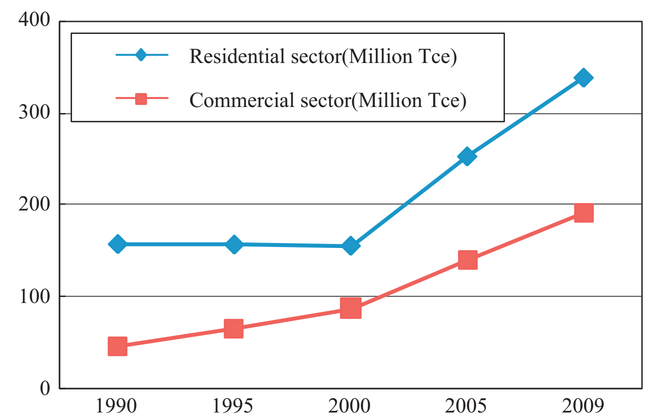


Fig. 3. Building energy consumpiton in residential sector and commercial sector in China.
Source: China Statistical Yearbook [1].

As shown in Fig. 2, the renewable energy consumption in the world increased from 74.5 million tce in 2000 to 230.6 million tce in 2010 with an annual increase rate of 12%. As for China, the renewable energy consumption has gained a rapid growth since the PRC Law of Renewable Energy went into effect in January 2006. For instance, the renewable energy consumption for China accounted for 7.6% of the total world renewable energy consumption in 2010 and the consumption has increased 16 times in the past decade [22]. According to the annual report of the United Nations Environment Program, China has exceeded the United States to become the country that made the most investments in renewable energy area in 2009.

2.2. Energy consumption in buildings

Buildings generally fall into two sectors, i.e. residential and commercial. The US Energy Information Administration predicted that the energy consumption in residential sector and commercial sector will increase 1.1% and 1.5% annually, respectively, from 2008 to 2035 [11].

As shown in Fig. 3, in 2009, the building sector consumed about 720 million tce, accounting for 17.3% of national overall energy consumption in China. Residential energy consumption has doubled to 338.43 million tce and energy consumption for the commercial sector has increased nearly 3 times since 1990. The commercial energy consumption and residential energy consumption together see a rapid growth from 2000. The trend of energy consumption showed that, as the living standard of people improved, together with a rapid development of tertiary industry, the rapid growth trend of energy consumption in buildings will

continue and the percentage of building energy consumption in national overall energy consumption may increase even further.

2.3. Renewable energy in buildings

2.3.1. Necessity and significance

The limited reserves of conventional energy resources have gradually become the bottleneck for economic development while the greenhouse gas emission is another issue associated with conventional energy sources [23,24]. There are also concerns on other types of alternative energy resources. For instance, the recent nuclear accident in Japan has triggered intensive public scrutiny on nuclear energy developments which has been slowed down. Germany will shut down all nuclear power plants by 2022 and Switzerland will abandon plans to build new nuclear reactors and phase out nuclear power in the future [25]. There have been calls for regulation reviews to avoid similar accidents [26,27]. Under such background, the growing energy consumption in buildings has played a critical role to achieve the strategic goal of sustainable development. Renewable energy, such as solar energy and wind energy with no greenhouse gas emission during power generation process, can be utilized in buildings to provide a solution to the problem [28]. For instance, solar water heater can save 10–15% energy consumption and solar heating system can create 45% energy saving in buildings [29]. The utilization of solar desiccant cooling system in institutional buildings can help to achieve 60% of energy related cost saving and significant reduction of greenhouse gas emission [30]. Similarly, utilizing renewable energy has become an important part of the design and development of green buildings [17,31,32].

2.3.2. Utilization of renewable energy in buildings

There is great potential to utilize solar energy, wind, geothermal energy and biomass in buildings and the technology is relatively mature. The utilization of solar energy has received increasingly level of attention worldwide, with inexhaustible source and no greenhouse gas emission and it can be utilized in photovoltaic systems, solar thermal water heating and hybrid photovoltaic–thermal solar systems, etc [33–35]. Wind energy is mainly utilized for power generation, especially in the high-rise buildings [36,37]. Geothermal energy is another vast clean energy source, stored in the interior of the earth. The heat pump technology is drawing rising attention and it has an enormous application potential in buildings [38,39]. At present, the available biomass contains crop straw, fire wood, livestock manure, industrial organic waste and municipal solid waste, etc. They can be utilized for heating through direct combustion or chemical conversion [40,41]. For instance, biogas can be generated from livestock manure through biochemical conversion.

3. Policy analysis of renewable energy in buildings

3.1. Policy on renewable energy

In order to provide a good environment to the development of renewable energy, renewable energy policy has become a focus of national policy formulation and legislation in China. There are descriptions similar to "proactively developing solar energy, wind energy and geothermal energy" since the Sixth Five-Year Strategic Plan [42]. In 2005, the National People's Congress passed the Renewable Energy Law of PRC [43], specifying the legal framework of the development and utilization of renewable energy in China. Following this, the government promulgated a series of supporting policies and regulations to provide subsidies to the renewable energy industry and to improve the market mechanism.

3.2. Policy on promoting renewable energy in buildings

Renewable Energy Law of PRC advocates the utilization of renewable energy in buildings for the very first time in the form of law. This law was amended in 2010. This law clearly stated that the government encourages organizations and individuals to install and use solar water heating system, solar heating/refrigeration system, solar energy photovoltaic power system and other solar energy utilization system. The relevant departments of the State Council are responsible to formulate technical–economic policies and technical regulations to facilitate the integration of solar energy utilization system into buildings [44]. According to the rules of technical regulations, real estate developers should provide essential conditions for solar energy utilization in both design and construction stages of the development. For existing buildings, residents can install solar energy utilization system in accordance with technical regulations and industry standards. Similarly, it is encouraged to develop renewable energy in rural areas. According to the local conditions, the governments encourage the application of biomass, household solar energy technology, small scale wind energy technology and hydropower technology.

Following this, a series of policies on promoting renewable energy in building are promulgated by government departments (see Table 1). In terms of law, Energy Conservation Law of PRC and Circular Economy Promotion Law of PRC has been effect in 2007 and 2008, respectively [45,46], which have also clearly stipulated that renewable energy systems are encouraged in buildings, such as the solar PV system.

On January 2006, the regulation Temporary Management for the Price and Cost Sharing in Renewable Energy Power Generation, containing product subsidy, became effective [47]. The application scope of the policy includes wind power generation, biomass power generation, solar power generation and geothermal power generation which all can be put into operation in buildings. Furthermore, the consumers are encouraged to purchase electricity from renewable energy resources which promotes the utilization of renewable energy in buildings. In 2007, Ministry of Construction published Technical Catalogue on the Eleventh Five-Year Application of Renewable Energy in Buildings [48] which promotes the application of renewable energy and guides the development of renewable energy utilization in buildings, especially in demonstration sites.

In 2009, two implementation schemes were promulgated to promote application of renewable energy in building for both urban and rural areas, respectively [49,50]. As for urban areas, demonstration sites will be established to expand the scale of application of renewable energy in buildings. Supporting measures will be taken to improve technical level and strengthen management work. For instance, the government will improve the implementation of national technological standards for solar energy techniques and cooperate with professional technical organizations to provide better technical support. Key regions in rural areas are identified to prioritize the utilization of renewable energy in buildings according to local conditions. For instance, buildings in primary and middle schools can install renewable energy utilization systems. Furthermore, central authorities will provide appropriate financial support to establish the demonstration sites.

In March 2011, Ministry of Finance and Ministry of Housing and Urban–rural Development promulgated Notice on Further Promoting Application of Renewable Energy in Buildings [51]. Objectives are clearly stated to accelerate the utilization of renewable energy on large scale and local governments are encouraged to release mandatory policies for this purpose. At the end of year 2011, Interim Measures for the Collection and Use of Renewable Energy Development Fund was released [52]. The Measures clearly

Table 1
Policies on promoting renewable energy in buildings.

Policy	Promulgated time	Contents
Energy Conservation Law	1sOctobser 2007	Renewable energy utilization systems, such as the solar energy system, are encouraged in newly-constructed and existing buildings
Circular Economy Promotion Law	August 2008	In conditional regions, the units of building design and construction should make the most of renewable energy, such as solar energy, geothermal energy and wind energy, etc.
Temporary Management for the Price and Cost Sharing in Renewable Energy Power Generation	January 2006	Consumers are encouraged to buy renewable energy electricity from wind power generation, biomass power generation, solar power generation and geothermal power generation
Technical Catalogue of MinistryofConstruction on the 11th Five Year Application of Renewable Energy in Buildings	August 2007	During the Eleventh Five-Year period, promote the application of renewable energy and guide the development of renewable energy utilization technologies in buildings. Strengthen technical support for the demonstration sites established by Ministry of Construction and Ministry of Finance
Implementation Scheme for Demonstrated Application of Renewable Energy in Buildings in Cities	July 2009	During the 11th Five Year period, promote the application of renewable energy and guide the development of renewable energy utilization technologies in buildings. Strengthen technical support for the demonstration sites established by MinistryofConstruction and Ministry of Finance
Implementation Scheme for Speeding Up the Application of Renewable Energy in Buildings in Rural Areas	July 2009	In rural areas, according to local conditions, identify key areas for application of renewable energy in buildings. For instance, promote the utilization of solar water heating system and shallow geothermal energy in buildings in primary and middle schools. Promote and manage demonstration sites of the application of renewable energy in buildings
Notice of Ministry of Finance and Ministry of Housing and Urban–rural Development on Further Promoting Application of Renewable Energy in Buildings	March 2011	Clear objectives of the application of renewable energy in buildings and speed up the utilization in buildings on large scale. Based on the foundation of demonstration sites in cities and rural areas, the state encourages local governments to publish mandatory promotion policies
Temporary Management for Collection and Use of Renewable Energy Development Fund	December 2011	Renewable energy utilization projects in rural areas and farms and construction of independent renewable energy power system in remote areas and islands are supported
The 12th Five Year Plan of Shandong Province on Energy Conservation	October 2011	Promote utilization technology research and standard formulating on renewable energy in buildings and gradually establish assessment system about renewable energy construction application. Solar energy techniques are encouraged to use in energy-saving reconstruction work for existing buildings. Accelerate active and safe application of ground source heap pump technology in the regions with favorable conditions
Implementation Scheme of Shandong Province on the 12th Five Year Comprehensive Work of Energy Conservation and Emission Reduction	November 2011	In order to save energy and reduce emission in buildings, strengthen supervision and inspection on the application of solar/thermal integrated buildings and speed up the popularization and utilization of solar water heater in rural areas. Solar heating system in encouraged to use on large scale in industry, public institutions, business and residential life
The Building Energy Efficiency Strategic Plan for the Twelfth Five-Year period	May 2012	The overall aims, guiding principles and development path of building energy efficiency during the Twelfth Five-Year period were specified. Specific goals and plans for implementing renewable energy in buildings were set up
Notice on improving the policies relevant to renewable energy application in buildings and mechanisms for funds allocation	August 2012	The number of demonstrate cities for renewable energy application in buildings is controlled where the selection criteria was specified. The calculation formula for funds allocation is provided. Priority of funding is given to solar pv and solar heat water system in rural areas, affordable housing, schools and hospitals
Strategic Twelfth Five-Year Plan for Renewable Energy Development	August 2012	Further endorsed that the application of renewable energy in buildings will be encouraged by the government and funds will be made available

specified that the government will support the renewable energy utilization projects in rural areas, and farms and construction of independent renewable energy power system in remote areas and islands. These policies also promote the utilization of renewable energy in buildings, especially for the rural and remote areas.

As for the Shandong Province, two policies on energy conservation and emission reduction were successively promulgated by the end of 2011, i.e. The 12th Five Year Plan of Shandong Province on Energy Conservation, Implementation Scheme of Shandong Province on the 12th Five Year Comprehensive Work of Energy Conservation and Emission Reduction [53,54]. Goals and measures are stipulated in these two policies to promote the renewable energy utilization in buildings. As one of pillar superior industries in Shandong, solar energy industry is the key area of establishing the development and assessment systems. Similarly, ground source heat pump is encouraged to be broadly implemented. All these national and provincial policies are summarized in Table 1.

Similarly, renewable energy application has featured in a number of building energy efficient design and assessment codes in China (see Table 2). China is a large country in terms of geography accordingly temperatures vary significantly from northern part of the country to the southern part of the country during the same season, especially during winter. The Chinese Standard of Climatic Regionalization for Architecture divides the country into five zones, i.e. Cold; Very cold; Hot summer and cold winter; Hot summer and warm winter; and Moderate [55]. As shown in Table 2, specific standards and codes have been designed to address the different climatic characteristics in different climate zones.

4. Analysis of renewable energy in buildings

4.1. Renewable energy utilization in buildings

4.1.1. Amounts and situations

Solar energy can be utilized through photovoltaic cell, solar water heater and solar air conditioning system in buildings. In China, the solar water heater is the most widely used technology,

Table 2
Standards and codes on building energy efficiency and renewable energy application in buildings.

	Codes and standards	Issue year	Notes
1	Code of thermal design for residential buildings	1986	JGJ24-86
2	Energy conservation design code for heating residential buildings	1986	JGJ26-86
3	Lighting Design Code for Civil Building	1990	GB 133-90
4	Code of thermal design for residential buildings	1993	GB50176-93
5	Energy conservation design standard for heating new residential buildings	1995	JGJ26-95
6	Standard for energy-efficiency inspection of heating in residential buildings	2001	JGJ132-2001
8	Technical specification for energy conservation renovation of existing heating in residential buildings	2001	JGJ129-2000
9	Design standard for energy efficiency of residential buildings in hot summer and warm winter zone	2003	JGJ75-2003
10	Design Code for heating, ventilation and air conditioning	2003	JGJ19-2003
11	Technical conditions and experimental methods for domestic solar PV system	2003	GB/T 19064-2003
12	Design Standard for the energy efficiency in public buildings	2005	GB50189-2005
13	Technical specification for solar water system in residential buildings	2005	GB50364-2005
14	Evaluation standard for green building	2006	GB50378-2006
15	Technical guidance for data monitoring system for the demonstration project of renewable energy in buildings	2009	
16	Technical specification for solar heating systems	2009	GB50495-2009
17	Technical specification for geothermal heat pump systems	2009	GB-50366-2009
18	Design standard for the energy efficiency of residential buildings in the hot summer and cold winter zone	2010	JGJ 134-2010
19	Design standard for energy efficiency of residential buildings in Cold and Very Cold zone	2010	JGJ26-2010
20	Technical specification for solar PV system in residential buildings	2010	JGJ203-2010
21	Design standard for energy efficiency of residential buildings in hot summer and cold winter	2010	JGJ134-2010

Table 3
Annual production and installed area of solar water heater in China.
Source: Status of solar thermal industry in China [34]; Research report about the development of solar water heater in China [58].

Year	Annual production (million m^2)	Change over last year (%)	Installed area (million m^2)	Change over last year (%)
1998	3.5	–	15	–
1999	5	42.9	20	33.3
2000	6.4	28	26	30
2001	8.2	28.1	32	23.1
2002	10	22	40	25
2003	12	20	50	25
2004	13.5	12.5	62	24
2005	15	11.1	75	21
2006	18	20	90	20
2007	23	27.8	108	20
2008	31	34.8	125	15.7
2009	42	35.48	145	16

Table 4
Annual and accumulative installed capacity of solar PV in China.
Source: New energy industrial development plan (draft) [61]; Research report on China PV industry (2006–2007) [62].

Year	Annual installed capacity/kWp	Change over last year/%	Accumulated installed capacity/kWp	Change over last year/%
1980	8	–	16.5	–
1985	70	–	200	–
1990	500	–	1780	–
1995	1,550	–	6630	–
2000	3,300	–	19,000	–
2002	20,300	–	45,000	–
2004	10,000	–	65,000	–
2005	5,000	−50	70,000	7.7
2006	10,000	100	80,000	14.3
2007	20,000	100	100,000	25
2008	45,000	125	145,000	45
2009	13,5000	200	300,000	106.9

ranked No.1 in production and utilization around the world [56]. The installed area increased over 9 times, from 15 million m^2 to about 145 million m^2, in the last twelve years (see Table 3) [57,58]. In 2006, the installed area accounted for 60% of the total area around the world, coving 40 million families and more than 150 million people [59]. This proportion increased to 76% in 2009 [58].

The development of solar PV in China falls behind compared to Japan, United States and Germany, etc [60]. However, during the last few years, China's solar PV industry is developing rapidly due to preferential policies. As shown in Table 4, the annual installed capacity of solar PV power almost tripled in the last five years, increasing from 135 MW in 2005 to 156 MW in 2009. The accumulated installed capacity increased over 15 times in last decade.

The combination of wind energy generation with buildings is another approach to utilize renewable energy in buildings. Britain, Sweden, Netherlands and other developed countries have promoted the research and practice on wind energy generation in cities and high buildings since 2001. This helps to avoid the remote transmission of electricity and lower the investment cost [63]. The rapid urbanization in China has produced a large amount of buildings that can be integrated with small scale wind turbines.

The geothermal energy can be utilized through heat pump technology in buildings which saves 30–70% energy than conventional heating and refrigeration equipment [64]. The Chinese government encourages the development of heat pump technology, especially in hospitals and schools. According the statistics of more than 160 heap pump projects, the technology has been used in various buildings in China [65] (see Fig. 4). For heating area, about 14% of the projects are over 50,000 m^2; 48% of the projects are 10,000–50,000 m^2; 39% of the projects are under 10,000 m^2. According to the official statistics, geothermal heating area in China increased rapidly, increasing from 1.9 million m^2 in 1990 to 11 million m^2 in 2000 [66]. By the mid of 2008, the heating (refrigeration) area reached to 80 million m^2 with an annual increase rate of 20% [67]. Hence, there is a promising market to utilize geothermal energy in buildings.

The main approach for biomass utilization in buildings is biogas generation in rural and remote areas. In recent years, Chinese governments at all levels have paid more attention to the construction of biogas facilities in rural areas and have established a rigid policy support and regulation mechanism. The investment on rural biogas facilities construction increased from 0.84 billion RMB in 2003 to 2.5 billion RMB in 2006 [68] and the biogas projects increased from 13.2 million in 2003 to about 20 million in 2006 [69]. By the end of 2006, the population accessed to biogas energy increased to more than 75 million. The biogas output amounted to 8.7 billion m^3, creating the total income of 7 billion RMB for farmers [70].

4.1.2. Major barriers

The research and practice on integration of renewable energy in buildings is not adequate in China and the immature technology is one of key barriers for the further development. Other barriers include the lack of complete national standards and industrial standards of related technologies and products; and lack of security architecture of products and facilities [18]. For example, under a strict national production standards system, the solar water heater in Australia can guarantee 12-year or even 20-year working life. Whilst in China, the product quality is comparatively poorer and the maintenance cost is higher, which gradually becomes a barrier for the development [71]. The high initial cost of renewable energy development compared to the conventional energy is another significant barrier. The imported equipment from overseas cost around 60% higher than those purchased locally. This limits the extensive utilization of renewable energy. Usually, the grid companies are required to pay a higher price for electricity generated from renewable energy than that from coal-fired generation and as a result the profit is much lower [7]. Although solar water heater is very popular in China, the inadequate supply chain has significantly restricted the application of solar PV in buildings in China. Over 90% raw materials for solar PV are imported whereas over 90% products are exported [72]. As a result, the profit level of the solar PV industry in China is comparatively low whereas the associated greenhouse gas emissions are considerably high. Furthermore, the Chinese solar PV industry needs further rigid policy supports. Although related policies have been promulgated by the government, substantial supports are far from adequate. For instance, under the "Million Solar Roofs" scheme, a large number of buildings in U.S. are almost self-sufficient in electric power by the end of 2010, which has significantly exceeded the development in China [73]. The utilization of wind energy in buildings is at the initial stage. Many theoretical and experimental works are exploratory rather than providing an accurate description of the technology [74,75].

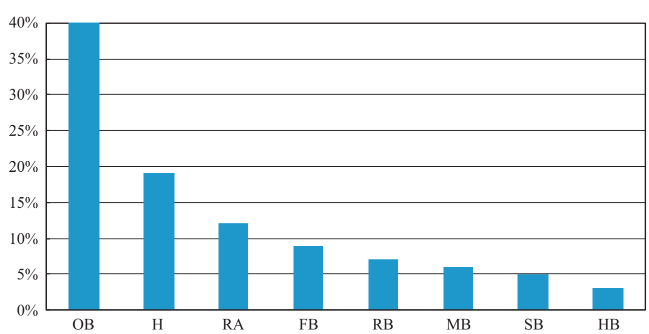


Fig. 4. The proportion of different buildings in 160 heap pump projects. *Note*: OB: office building, H: hotel, RA: residential area, FB: factory building, RB: resort building; MB: market building, SB: school building, HB: hospital building.

4.2. Development plan for renewable energy in buildings in China

The Chinese government has recognized the significance of utilization of renewable energy in buildings and has developed a strategic plan accordingly. In 2007, the government promulgated the Medium and Long-term Development Plan for Renewable Energy [10]. Goals were established to promote industrialization development in wind energy generation, biomass generation, and solar energy generation, aiming to increase the proportion of renewable energy in overall energy consumption to 10% and 15% in 2010 and 2020, respectively. According to this strategic plan, the amount of renewable energy utilized in buildings will dramatically increase (see Table 5). These strategies and ambitious goals are further endorsed in the recently released Strategic Twelfth Five-Year Plan for Renewable Energy Development. These renewable energies resources are: biogas, solar PV, solar water heater and geothermal. As shown in Table 4, the development plan for renewable energies in buildings is explicit. There are other strategic plans for the utilization of renewable energy in buildings. For instance, by the end of Eleventh Five-Year Plan, the utilization area of solar energy and shallow geothermal energy should cover more than 25% of the new construction area and the proportion should exceed 50% by the end of 2020 [76]. 386 demonstration projects for renewable energy application in buildings and 47 demonstration cities were set up with a total floor area of 3.89 million m^2 during this period of time [51]. This is equal to 20 million tce. The Building Energy Efficiency Strategic Plan for the Twelfth Five-Year period was released by the Ministry of Housing and Urban–Rural Development in May 2012 which clearly specified the goal of adding an extra 2.5 billion m^2 floor area of buildings with application of renewable energy with a capacity to reduce 30 million tce of conventional energy consumption by 2015 [77]. Furthermore, renewable energy accounts for more than 15% of building energy consumption in 2020 [51].

As for Shandong Province, the developing plan for renewable energy in buildings is ambitious. By the end of 2015, over half of the new buildings will use renewable energy and the new application area of renewable energy will reach to 18 million square meters among witch the solar energy covers more than 83% [53,54]. It is interesting to note that the utilization of wind power in buildings was not reported in any strategic plan. The current focus of all policies and strategic plans on wind energy is predominately on the large scale grid-connected wind farms.

Table 5
Develop goals for renewable energies in China.
Source: Medium and long-term development plan for renewable energy [10].

Items	Development plan
Biogas	Promote the application of biogas in rural areas and small-medium sized cities. By the end of 2020, the biogas production reaches to 30 billion m^3, coving 300 million people
Solar PV generation	In remote areas, adopt household solar PV generation systems or small PV stations. The solar PV generation capacity reaches to 0.3 million kW by the end of 2020. In large-medium sized cities with higher economy and modernization level, develop PV grid-connected generation systems and building integration. By the end of 2020, the amount of the projects increases to 20 thousand and the generation capacity reaches to 1 million kW
Solar water heater	Popularize integration of solar water heater with buildings and central solar heating systems in cities. Set demonstration sites to utilize solar heating/ refrigeration systems. In 2020, the amount increases to 300 million m^2, replacing 60 million tce with the addition of other forms of solar thermal utilization
Geothermal energy	Utilize geothermal energy reasonably and promote technologies satisfying the requirement of environmental and water resource protection. In Yangtze river area and coastal areas, utilize shallow geothermal energy to supply air conditioning system and daily life with hot water. By the end of 2020, the utilization of geothermal energy amount to 12 million tce

5. Conclusions

Renewable energy plays a critical role to satisfy rising energy demands and to achieve low-carbon economy. The utilization of renewable energy in buildings has been an important way to promote the development of renewable energy. China is rich in renewable energy sources where different types of renewable energy develop rapidly, especially in buildings. Renewable energy policy has become a focus of national policy formulation and legislation. From 2007, the government has promulgated more than a dozen national policies to promote the utilization of renewable energy in buildings. However, China is still at the early stage compared to the developed countries. The immature technologies, lack of comprehensive product standards, inadequate supply chain and high cost are major barriers to the further development of renewable energy in buildings. A more rigid policy system is required and further research works are encouraged to facilitate the utilization of the renewable energies in buildings. It is worth noting that even though a number of strategic plans have been released to promote the utilization of renewable energy in buildings, wind energy seems out of the radar as the current focus is placed on large scale wind farm developments that have connected to the power grid.

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